AD-A138 885 THE USE OF GENETIC MECHANISMS AND BEHAVIORAL CHARACTERISTICS TO CONTROL N..(U) VIRGINIA POLYTECHNIC INST AND STATE UNIV BLACKSBURG DEPT OF E.. 1/1

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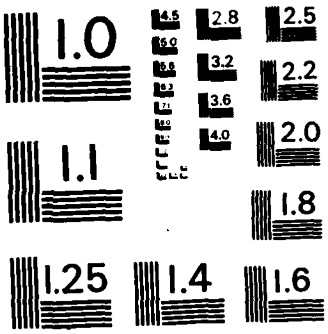

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OFFICE OF NAVAL RESEARCH

Contract #N00014-77C-0246

Task No. NR 205-028

ANNUAL REPORT NO. 1

The Use of Genetic Mechanisms and Behavioral Characteristics to Control Natural Populations of the German Cockroach

by

Mary H. Ross and Donald G. Cochran

Department of Entomology
Virginia Polytechnic Institute and State University
Blacksburg, Virginia 24061

March 1984

This research was supported in part by the Office of Naval Research, Microbiology Program, Naval Biology Project under Contract N00014-77C-0246.

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	2. GOVT ACCESSION NO. AD-A138 885
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle) The Use of Genetic Mechanisms and Behavioral Characteristics to Control Natural Populations of the German Cockroach	5. TYPE OF REPORT & PERIOD COVERED Annual 3/1/83 - 2/29/84
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Mary H. Ross, Donald G. Cochran	8. CONTRACT OR GRANT NUMBER(s) N00014-77-C-0246
9. PERFORMING ORGANIZATION NAME AND ADDRESS Virginia Polytechnic Institute & State University, Blacksburg, Virginia 24061	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Office of Naval Research, 800 N. Quincy Street, Arlington, Virginia 22217	12. REPORT DATE March 1, 1984
	13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report) Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Distribution of this is unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

Accession For	
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A-1	

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

German cockroach
Cockroach behavior
Cockroach control

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Experiments conducted in 1983 are focused on the behavior of German cockroach populations. The research is directed towards elucidating behaviors that were discovered in prior laboratory and "field" (inactive ship) experiments and in expanding this work to include the effects of an insecticide.

Our laboratory study of within-harborage aggregation provided evidence that responses to naturally-occurring chemical cues (pheromones) differ with

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S/N 0102-LF-014-6601

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) age class and adult sex. Moreover, production by females varies with female reproductive state and density. Experiments using a bioassay technique confirm differences in the response to aggregation pheromone with age/sex class. Data have been gathered from 288 individuals of 6 classes (small nymphs, medium-sized nymphs, large nymphs, adult males, egg case bearing females, and non-egg case bearing females). Differences occur in the time of response, intensity of the attraction, and relative attraction to papers with prior exposure to egg case (gravid) vs non-egg case bearing (non-gravid) females. The behaviors correlate well with shipboard experiments in which small nymphs generally remained concealed in harborages and medium and large sized nymphs tended to disperse widely. A bioassay technique is also being used to study the production of and response to a repellent that is obtained by crowding adult females. Filter papers exposed to large numbers of both gravid and non-gravid females are avoided by adult males. We are currently experimenting with reducing the repellency in order to compare relative avoidance with age class and with production by gravid vs non-gravid females.

The research on insecticide-induced behavior (dispersal) is a blend of laboratory and shipboard experiments. Laboratory studies show strong dispersal of both the VPI susceptible and a field-collected resistance strain following exposure to vapors from baygon (propoxur). Overall, less dispersal is seen in the resistant strain. The greatest difference lies in that there is much less dispersal by small nymphs than by either medium-sized (3rd-4th instar) nymphs, adult males, or adult females, regardless of the particular strain.

The first shipboard study on the effects of an insecticide (baygon) was conducted in 1982. Information useful to the 1983 experiments included evidence that distribution stabilized at 2 wks post-treatment. Also estimates of percent kill and dispersal could be used for comparison to results on wild-type resistant cockroaches in the 1983 experiments. The latter used populations composed of equal numbers and similar stages of a wild-type resistant strain (w.t.-R) and a susceptible strain homozygous for orange-body, a mutant that is readily identified in all life stages (or-S). The first experiment was terminated early because a rat disturbed the population. Nevertheless, the numbers of each strain accounted for by initial and final collection were closely similar, and a higher kill of the or-S strain was in general agreement with two additional experiments. The latter were conducted simultaneously, one in a location not used in previous work. The results were closely similar. Trapping data prior to treatment showed most cockroaches were at or near the location where they were released and, among the few that did disperse, the numbers of w.t.-R and or-S were nearly equal. Dispersal subsequent to treatment with baygon was also similar. Nevertheless, both experiments showed substantially higher kill of the or-S strain, particularly among the adults. In the w.t.-R strain, there was less difference with age class. Neither strain showed a higher kill of small nymphs, as would be expected if their tendency to disperse less than other age classes made them more vulnerable to treatment. The differential kill of the two strains was clearly due to physiological resistance. The laboratory experiments showed baygon vapors have a strong repellent effect, but apparently this was not a major factor in determining the immediate effectiveness of a "field" application.

The shipboard experiments would not have been possible without the continued fine cooperation from the Navy Environmental and Preventive Medicine Unit 2, Norfolk, Va., especially of our liason officer, LCDR McCroddan. They were very helpful in making arrangements with the Portsmouth Inactive ship facility for access to an inactive ship.

The German cockroach, Blattella germanica (L.), has been the subject of numerous biological studies. Nevertheless, there is a dearth of information on population behavior. Population behavior reflects that of individual components that comprise the total population. German cockroach populations contain nymphs in 6 or 7 stages of development, adult males, and adult females in various phases of their reproductive cycle. Earlier Navy-supported research conducted in our laboratory revealed differences in the aggregation and dispersal behavior among members of a mixed age group. Moreover, the reproductive state and density of adult females in the group affected the behavior of all its members. Additional data on growth and behavior were obtained from experiments on a free population that were conducted on an inactive ship in 1981. The latter provided the basis for a pilot study on the effects of insecticides on a free population in 1982. Work begun under the present 3-year Contract continues these studies. The initial laboratory experiments are focused on the response of specific age classes to naturally-occurring chemical stimuli (aggregation pheromone and a repellent) and to exposure to vapors from an insecticide. Shipboard studies are directed towards comparisons of the effects of insecticide treatment on a susceptible and resistant strain.

Accomplishments of the past year are summarized below according to the objectives stated in the Contract proposal.

Objective 1 - To complete the compilation and analysis of data from prior experiments on the inactive ship (1981 and 1982) and to prepare the material for publication.

An article summarizing the 1981 study has been prepared for publication in Naval Research Reviews (spring issue 1984). A manuscript reporting the experiment in detail is nearly ready for submission to a scientific journal. All collections from the 1982 study have been counted and the data are being compared to those from experiments conducted this past summer (see Obj. 2b).

Objective - 2 To investigate the effects of insecticide treatment on the behavior of susceptible and resistant members of a mixed, genetically-marked population and to study the mechanism(s) underlying any observed differences.

a. Laboratory experiments

This work is being conducted by the graduate student, Mr. Brian Bret, who is receiving support from this Contract. He has carried out experiments that test the response of two strains, the VPI susceptible strain and a propoxur-resistant strain (Bowling Park), and their constituent age classes, to vapors from propoxur (baygon). The results are currently being analyzed with the help of the VPI Dept. of Statistics.

The experiments utilized mixed age groups of each strain (10 non-egg case bearing females; 10 adult males; 10 medium-sized nymphs (3rd-4th stage), and 10 small nymphs (1st-2nd stage). In brief, a group was held in one aquarium (5 gal.) until it had aggregated on 3 W-shaped pieces of filter paper nestled against each other. A weight pan with either 5 ml. of Risella oil (control) or 1% propoxur in oil was then introduced and, simultaneously, a seal that had prevented access to a 2nd aquarium through plastic tubing was removed. Movement of cockroaches was recorded at 15 min intervals for the 1st hour and at every half hour for the next 5 hours. The total data show most of the cockroaches exposed to propoxur vapors had dispersed from the 1st aquarium by the 3rd hour (Fig. 1). The rate of dispersal was similar in the two strains, but the amount of dispersal was less in the resistant strain (Fig. 2). In both strains, most of the dispersal was by medium-sized nymphs and adults. Small nymphs showed little dispersal (4% in the VPI and 6% in the resistant strains); that of mid instars and adults ranged from 23-37 % in the susceptible and from 31-32% in the resistant strain.

The resistant strain was recently collected from a housing project. Exposure to chemical control had developed a resistance level of about 8-9X to propoxur (LC_{50}). If a behavioral resistance promoting escape by dispersal had also been developed, the data should have shown more dispersal by the resistant strain. This was not the case.

Preliminary work on exposing antennae to propoxur vapors and recording the results by electroantennagrams has been initiated.

b. <u>Shipboard studies</u>

The 1983 experiments were based on prior studies conducted in 1981 and 1982 on board an inactive ship. In the 1981 experiment on wild-type growth and behavior, groups of cockroaches (aggregations) were established in known harborages at various locations throughout the galley and surrounding area. One such location had the characteristics we desired for studies on the effects of insecticide treatment. Harborage was sufficient for development of a very large group and there was little dispersal from the group. In 1982, a single, large population of a field-collected resistant strain (9X resistance baygon, LC_{50}) was established in the chosen location (Fig. 3, site 2). Five traps not shown in Fig. 3 were added in the area around site 2. Trapping data showed that dispersal following an initial treatment with 1% baygon in oil with flushing with pyrethrins was mainly into the area surrounding the treated area (into and around harborages at site 2) although some widespread dispersal occurred. By 2 weeks after treatment, the situation had stablized. Approximately 80% of the cockroaches moved back to the original harborages, although new spots of concealment that were inhabited following dispersal were never entirely deserted. Subsequent trapping data showed no change from that at 2 wks. post-treatment.

The plan for 1983 was to conduct two experiments similar to that of 1982 except that: 1) the population would be equally divided between members of the wild-type resistant field strain (w.t.-R) and a susceptible strain homozygous for orange-body, a mutant that can be distinguished visually in all life stages (or-S); and 2) trapping data assessing dispersal would be limited to that collected 2 wks after treatment. The first experiment (Experiment 1) was initiated on 31 May. A carton containing 800 or-S and 8000 w.t.-R was left at site 2 (100 adult females with egg cases in the same stage of embryonic development; 100 adult males; 300 medium-sized nymphs (3rd-4th instar); and 300 small nymphs (1st-2nd instar). Ten days later we returned to collect trapping data and to conduct an initial treatment. The carton was chewed and pulled well away from site 2. Our helpers from EMPU-2 (Lt. Robert Gay and HM1 Slinker) quickly recognized the work of rats. However, trapping data showed most of the cockroaches were still around site 2, although some had dispersed along a nearby steam table (Fig. 1, sites 3B and 3). Therefore, we proceeded with the initial treatment (11 oz. of 1% baygon in oil sprayed into and around harborages at site 2). Data were collected on kill and immediate dispersal. The experiment was terminated with a heavy treatment (cleanout) with D-phenothrin 2 days after the initial treatment.

Experiment 2 was scheduled for 29 August - 14 September. It was conducted as planned. The population was doubled over that of Experiment 1. The continued fine cooperation from EMPU-2 was extended to rat extermination prior to the experiment. A third experiment was conducted at the same time in a part of the ship not used previously. The population consisted of 150 males, 150 females, 450 medium-sized and 450 small nymphs of each strain.

The shipboard experiments are focused on two problems concerning which there is a wealth of speculation but a dearth of data, specifically: 1) how levels of physiological resistance determined in laboratory tests affect the success of measures used to control cockroach infestations and 2) whether physiological or behavioral resistance is the major factor when strain differences in resistance (differential kill) are present.

Table 1 summarizes data on percent kill from all experiments. A slight tendency in the resistant (w.t.-R) and a strong tendency in the susceptible strain (or-S) towards higher kill of adults than nymphs is evident. If each experiment is weighted equally, the mean kill of adults of the w.t.-R strain is 21% compared to 17% for nymphs; in the or-S strain, 40% adult compared to 26% nymphal kill. Kill did not vary markedly with age class in the w.t.-R strain. Overall, a higher kill is evident for the or-S strain, with the greatest difference between the strains due to the comparatively high kill of or-S adults.

The only discrepancy was in kill of or-S females in Experiment 1 (8% compared to 12% w.t.-R), although kill of males was in line with that of the other experiments (11% vs 21%). The number of or -S females unaccounted for in Experiment 1 was considerably smaller than that of other age classes (Table 4), a situation that may have arisen from dispersal caused by rats and that might account for the low number and percent killed.

The above documents a difference in kill between a strain with a 9-fold resistance to baygon (LC_{50}) and a laboratory susceptible strain. The next question is whether insecticide-induced dispersal played a significant role in the higher survival of the resistant cockroaches. These data are limited to Experiments 2 and 3.

Only 3 cockroaches were trapped other than directly at site 2 prior to treatment in Experiment 2. At 2 wks post-treatment, 18 w.t.-R and 19 or-S cockroaches were trapped at other sites. Traps added around the perimeter of the treated area at site 2 accounted for 7 of the w.t.-R and 4 or-S cockroaches; those at or associated with sites 1 and 3, for 6 w.t.-R and 13 or-S. The remainder consisted of 1 or 2 cockroaches at sites 5 and 6 and 1 or-S at site 9 (Fig. 3).

The new area where Experiment 3 was conducted was very different from the main galley. It was a series of 4 small rooms, with carpeting on the floor and wooden cabinets and some other furnishings still present. Loose margins of the carpet provided opportunities for concealed routes of movement, but most of the population stayed in the same corner of the small rooms where it was released. Prior to treatment, very few cockroaches were trapped elsewhere (2 or-S in other parts of the room; 3 w.t.-R and 3 or-S trapped in the adjoining small rooms). Since time allowed on the ship was insufficient to conduct two "cleanout" operations in one day, Experiment 3 was terminated one day earlier than Experiment 2. Dispersal data were thus limited to one instead of two night's trapping. However, the results were similar to those from Experiment 2 in that there was little, if any, difference in dispersal of or-S and w.t.-R cockroaches. Dispersal into new parts of the room where the cockroaches were released was evidenced by catch of 6 w.t.-R and 5 or-S cockroaches; that to the other small rooms, by 7 w.t.-R and 9 or-S.

The close similarity in both pre-treatment and post-treatment distributions of or-S to those of w.t.-R argues against an hypothesis that behavioral differences accounted for the higher kill of the susceptible strain. Both dispersed about equally following the initial treatment.

Several points of interest emerge from consideration of the individual experiments, (Tables 2-10), for example:

Experiment 1

a. Few cockroaches remained in the carton at 2 days post-treatment, although visual examination had shown a large number still present after disturbance by the rat (Table 3). Those few that did not disperse following the initial treatment were mainly small nymphs. Our shipboard and laboratory studies have already shown that small nymphs have an over-riding need for concealment. Small or-S outnumbered the w.t.-R nymphs, although the situation was reversed in the cleanout collection. The reason for this difference in distribution is uncertain. A difference in the relative numbers in the carton after disturbance by the rat (prior to treatment) is one possible explanation.

Experiment 2

b. The higher kill of or-S cockroaches in Table 5 is in agreement with final collections in Table 6 that show fewer survivors of the or-S strain.

c. The higher kill of or-S females is reflected in lower numbers of newly-hatched nymphs from the surviving females (Table 6, Sm. ny.).

d. Table 7 shows an overall close agreement between the numbers of each strain that were accounted for by initial and final collections. There is less agreement when an attempt is made to recognize age classes of the initial population among the final collections. Differences here suggest more 3rd than 4th instar among the "medium-sized" w.t.-R nymphs of the release groups than among the or-S nymphs. If so, w.t.-R "Ad & md. ny." in Table 7 are underestimated, since time was insufficient for maturation of many 3rd instars; conversely, the "sm.ny" are overestimated due to inclusion of medium-sized nymphs of the original group.

Experiment 3

e. As in Experiment 2, a higher initial kill of or-S cockroaches (Table 8) is in agreement with final collections showing their lower survival (Table 9).

f. The higher kill of or-S females is again reflected in lower numbers of newly hatched nymphs from the surviving females (Table 9).

g. Comparison of numbers accounted for in Table 10 are closely similar to the results for Experiment 2 in Table 7. Estimates for particular age classes again suggest more 3rd instar among the "medium-sized" nymphs of the w.t.-R releases than among the or-S, especially since these two experiment were concurrent (w.t.-R drawn from the same nymphal jar and likewise the or-S, with jars containing nymphs known to have hatched within the same week).

h. A difference in harborage related to the new location used in Experiment 3 is apparent in the numbers of cockroaches in the cartons. Very few were present at 2 wks. post-treatment (Table 9), but this was true prior to the insecticide application. The cockroaches apparently preferred cracks in and under wood paneling behind the carton to the carton itself. Several experiments involving the other location have shown the cartons to be the main harborage (1981, 1982, and Experiment 2, 1983). However, at other sites used in the 1981 experiment, there were two instances where nearby shipboard harborages were preferred to the cartons.

In summary, it is evident that physiological resistance played a primary role in differential kill of susceptible and resistant cockroaches. Dispersal of the strain with the larger number of survivors (w.t.-R) was closely similar to that with fewer survivors, arguing against the idea that repellency was responsible for survivorship. Survivorship can probably be attributed to the relatively low amount of and small area covered by the treatment, i.e., that surviving cockroaches were those that received a sublethal dose of the insecticide. The laboratory experiment leaves little doubt that baygon vapors caused considerable movement, but this response does not appear to have been the primary cause of survivorship in the shipboard experiment. Possibly death from an insecticide occurs before cockroaches have a chance to respond to the repellent effects.

An advantage to the use of baygon shown by our experiments is that most of the dispersal was into the areas in the immediate vicinity of the treated location; widespread dispersal was minimal. Whether this holds true for pyrethroid insecticides needs to be explored. Dispersal was somewhat more widespread in the 1982 experiment where we used a few seconds of pyrethrin spray to flush cockroaches as part of the initial treatment but the numbers are too small to make a meaningful comparison to the 1983 data. Estimates based on the 1982 experiment suggest that treatment of infested harborages and the surrounding hiding places with concentrations lethal to resistant members of a population should kill at least 80-90% of the population. Perhaps the most serious threat from dispersal comes from a few cockroaches that escape into new areas. They may reduce the long-range effectiveness of control measures. New groups may form in situations that do not promote the development of large infestations, but the 1981 experiment showed that small groups may serve as a major source of cockroaches moving to more favorable locations. Moreover, the 1982 experiment showed that, once established, the small groups are likely to persist.

Objective 3 - <u>To explore further the apparent cyclic production of chemical stimuli by adult females, including definition of the types of responses produced and the effects of female density and reproductive state on levels of pheromone production.</u>

Two types of naturally-occurring chemical stimuli are under investigation. One is the well known aggregation pheromone; the other is a repellent. A bioassay approach is being used to investigate the responses of different age classes to these substances when produced by adult females. Two filter papers are exposed to either non-egg case bearing or egg case bearing females (non-gravid or gravid). Attraction from aggregation pheromone is obtained by prior exposure to 10 females for 3 days. The filter papers and a control paper are folded into a W-shape and placed on the bottom of a battery jar. The age class being tested is then introduced and data gathered either visually or by timed photography on the location of each cockroach. Thus far, 288 individuals of the following age classes have been tested for response to aggregation pheromone: small nymphs (1st-2nd instar), medium-sized nymphs (3rd-4th instar), large nymphs (5th-6th instar), adult males, gravid females, and non-gravid females. The results are summarized in Fig. 4. Additional control data are being obtained because there may be a slight effect from the position of the paper in each jar. The consulting service of the Dept. of Statistics is helping us to analyze the data. The results of each replicate for each age class have been entered on the computer. Differences in the time and intensity of the response are evident in Figure 5. Small nymphs show a particularly strong attraction to the papers with aggregation pheromone, which probably explains the strong tendency of this age class to remain within a harborage (both shipboard and laboratory experiments).

Crowding of either egg case or non-egg case bearing females causes production of a repellent. In our initial trials, 100 females were used, with a time of 45 min on filter papers placed in 350 ml. beakers. Subsequently, we have altered the procedure, using a 45 min exposure of filter papers to adult females in a 35 ml vial. A very strong repellent effect is evident. Replicates/age class are not yet sufficient to make meaningful comparisons.

Table 11 shows data from our preliminary tests using filter papers exposed to 100 adult females. The test insects were adult males. At 0.5 hrs., most were on the jar bottom. Movement onto the papers was evident at 1 hr., with the largest numbers on the control paper and that exposed to gravid females. At 1.5 hr., 32 were on the control papers, as compared to 16 on papers exposed to gravid females, 6 on those exposed to non-gravid females, and only 3 on the jar bottoms. A pattern was established at 2 hrs. in which there was little subsequent change. In 7 time intervals extending from 2.0-5.0 hrs., most of the 12 males within each replicate were on the control paper (9.86 ± 0.18). A particularly strong repellent effect is apparent in replicate 1, where cockroaches on exposed papers were limited to a single observation of one individual (2.5 hrs.). Several cockroaches were generally present on the exposed papers in replicates 2-5. They showed the trend established earlier (1 hr.) towards a larger number on papers exposed to gravid females. Possibly the initial response was to aggregation pheromone, with a subsequent, stronger response to the repellent.

Concluding Comments

Experiments conducted during this first year of the present three-year extension of this Contract have documented differences in the response to naturally-occurring and artificial chemical stimuli with age/sex class and with a resistant vs susceptible strain. This information and the continued study ˜ these variations will be a significant step towards re .ai.ag an understanding of the behavior of German cockroach pc lations. The role of physiological resistance in the "field" test has important implications for the use of insecticides control measures.

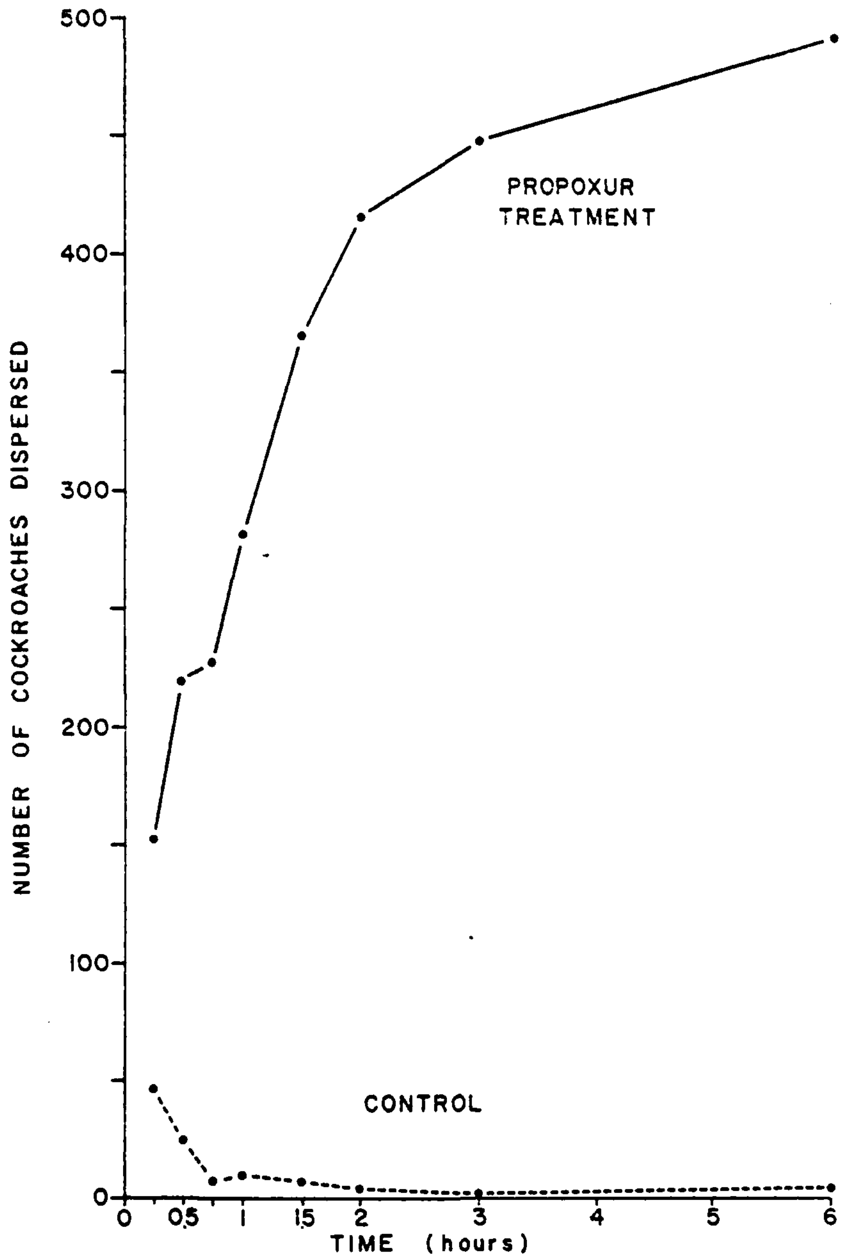

Figure 1. Combined data from the VPI (susceptible) and the Bowling Park (resistant) strains showing the overall response to vapors from propoxur.

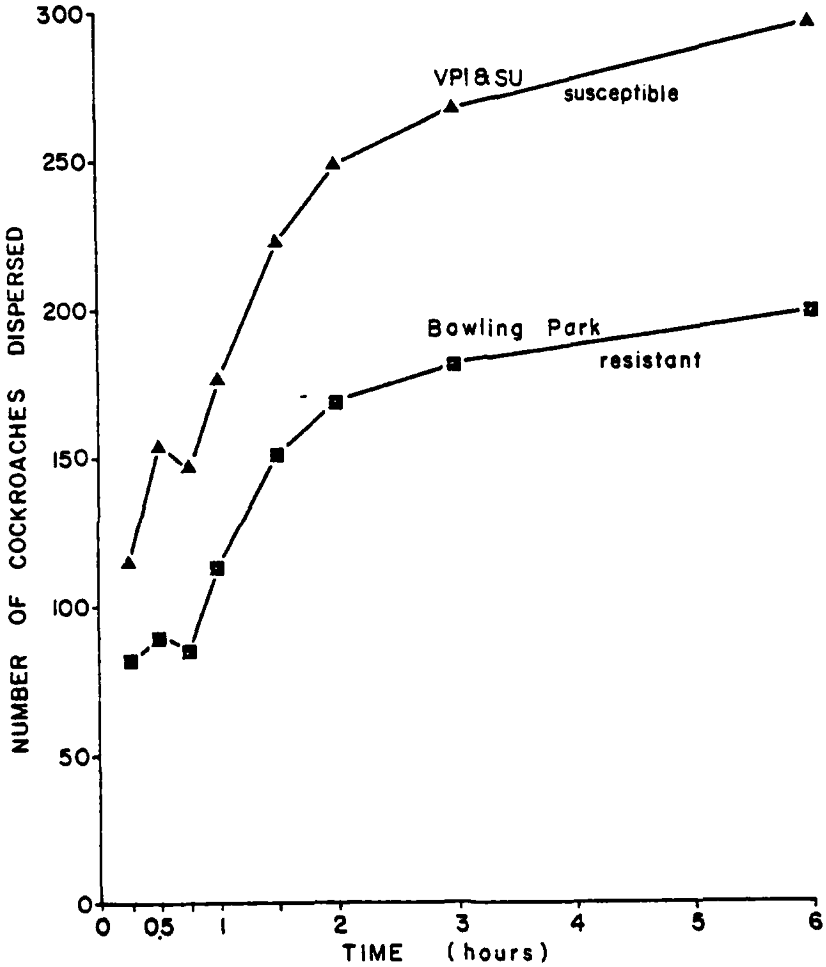

Figure 2. Comparison of the response of mixed age groups of VPI (susceptible) to Bowling Park (Resistant) cockroaches to vapors from propoxur.

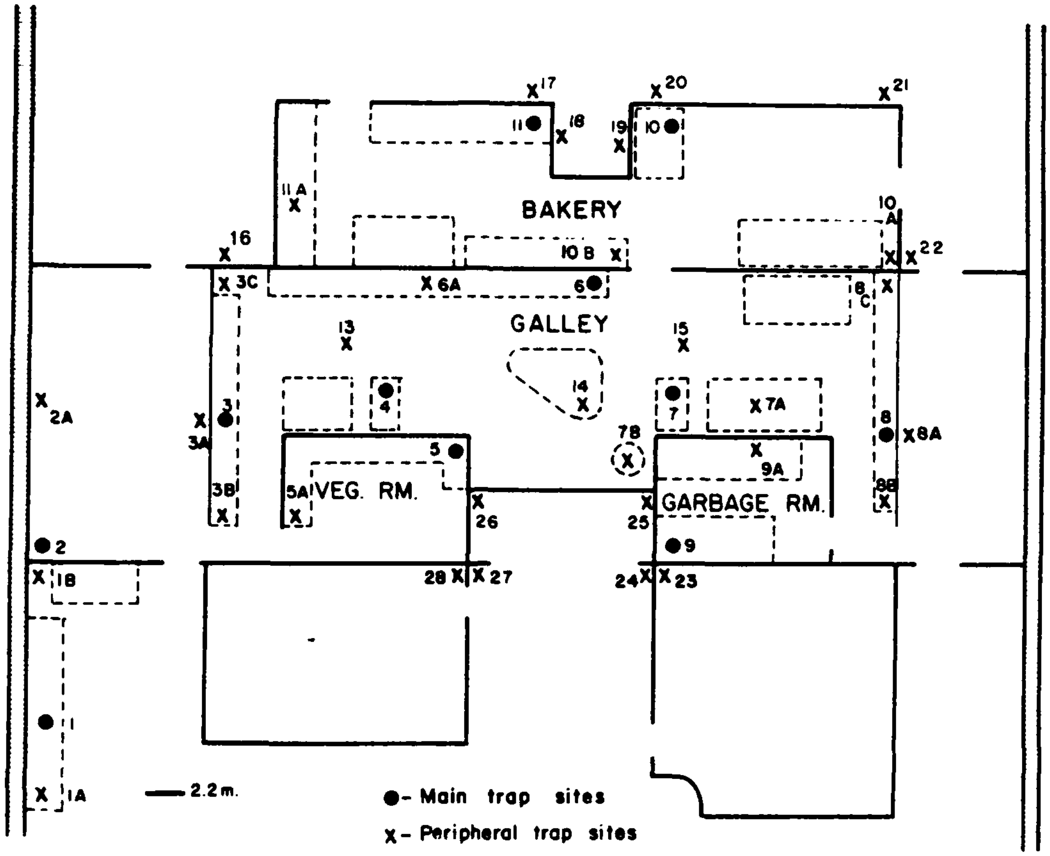

Figure 3. Trap sites used in experiments on an inactive ship. "Main" trap sites are locations supplied with water, food, and a quart-sized ice cream carton. Five additional traps added around site 2 in the 1982 and 1983 experiments are omitted.

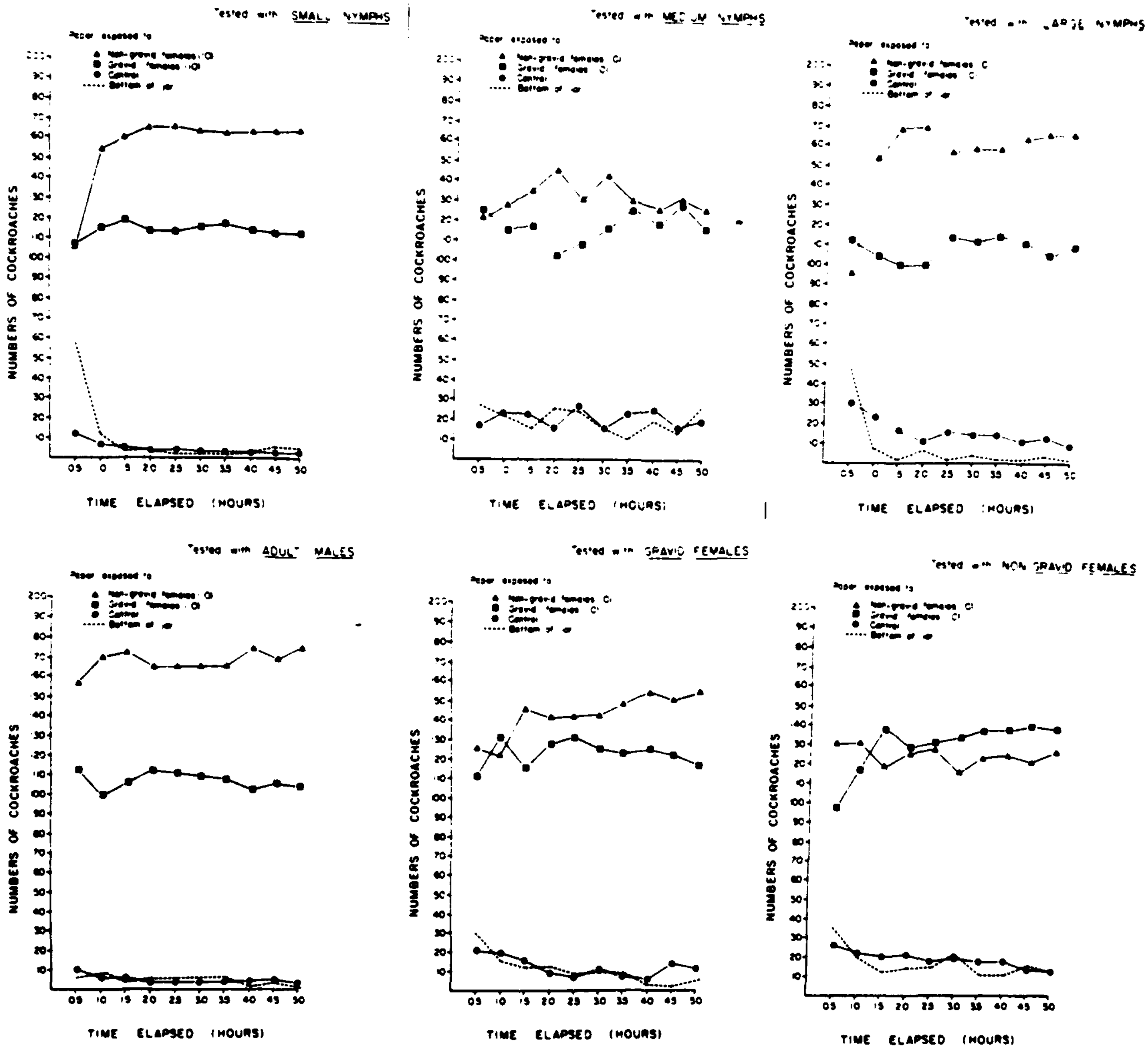

Figure 4. Response of specific age classes to papers exposed to either 10 gravid or 10 non-gravid females (aggregation pheromone).

SUMMARY FROM ALL EXPERIMENTS ON THE INACTIVE SHIP

Table 1. Comparisons of percent kill of *B. germanica* according to age class from several experiments on an inactive ship (initial treatments with 1% baygon in oil).

Strain[a]	Experiment	Age class[b]			
		Ad. ♀	Ad. ♂	Md. ny.	Sm. ny.
or-S	#1-1983	8%	21%	13%	28%
	#2-1983	57%	65%	17%	34%
	#3-1983[c]	41%	50%	27%	34%
Bl-S[d]	1982		42%		
w.t.-R	1982	28%	—[d]	10%	15%
	#1-1983	12%	11%	14%	11%
	#2-1983	15%	21%	8%	36%
	#3-1983	17%	39%	17%	22%

[a]or-S = orange-body susceptible strain; w.t.-R = wild-type resistant strain.

[b]Ad. ♀ - adult females; Ad. ♂ - adult males; Md. ny. - medium-sized numphs; Sm. ny. - small nymphs. The two nymphal age classes correspond to the release of medium-sized nymphs (3rd-4th instar) and small nymphs (1st-2nd instar).

[c]Experiment conducted in a different location than that of the other three experiments

[d]Black-body males that were almost, though not completely susceptible (2-3X resistance at LC_{50}) were used in the 1982 experiment in order to have an age class of the original population that could be identified at the conclusion of the experiment 5 wks post-release.

DATA FROM EXPERIMENT 1 (June 1983)

Table 2. Comparisons of kill of a susceptible (orange-body) strain to that of a baygon-resistant strain (wild-type) following an initial treatment with 1% baygon in oil.

Strain	Kill/age class				Overall kill	
	Ad. ♀	Ad. ♂	Md. ny.	Sm. ny.	No.	%[a]
or.-S	8	21	40	84	513	19
w.t.-R	12	11	43	34	94	12

[a]Estimate based on release of 800 of each strain.

Table 3. Collections at 2 days after the initial treatment (early termination due to rat problem).

Collection	Strain	Age class Ad.♀	Ad.♂	Md. ny.	Sm. ny.	Total
Carton	or-S	0	1	10	52	63
	s.t.-R	0	1	2	16	19
Cleanout	or-S	18	18	64	18	118
	w.t.-R	33	32	84	52	201
Total	or-S	18	19	74	70	181
	w.t.-R	33	33	86	68	220

Table 4. Comparison of total numbers of cockroaches caught to the numbers released.

Strain	No. collected[a]:no. released Ad. ♀	Ad. ♂	Md. ny.	Sm. ny.	Total
or-S	26:100	44:100	114:300	154:300	338:800
w.t.-R	45:100	40:100	129:300	102:300	316:800

[a]Total from initial treatment, final treatment, and cartons.

EXPERIMENT 2

Table 5. Comparison of kill of a susceptible (orange-body) strain to that of a baygon-resistent (wild-type) strain of *B. germanica* following an initial treatment with 1% baygon in oil

Strain	No. Killed Ad. ♀	Ad. ♂	Md. ny.	Sm. ny.	Total	% Kill
or - S	113	131	05	206	555	35
w.t.-R	32	42	49	183	306	19

Table 6. Collections at 2 weeks after initial treatment

Strain	Collection	Ad. ♀	Ad. ♂	Md.-lg. ny.	Sm. ny[a]
or-S	Carton	22	20	52[b]	43
	Cleanout	38	49	111	294
	Trap[c]	20	9	16	1
w.t.-R	Carton	61	53	113[d]	111
	Cleanout	63	74	181	535
	Trap[c]	35	16	28	17

[a]Small nymphs, most 1st instar. New additions to the population from hatch of egg cases of females in original population.

[b]Includes 7 very large nymphs (last few medium nymphs of original population).

[c]Trap bagged and counted in lab.

[d]Includes 6 very large nymphs.

Table 7. Comparison of the totals of all collections to those of the original population.

Age class	No. rel.	Initial kill	Survivors[a]	Cockroaches accounted for: No.	%
		or-S			
Ad. & md. ny.	1,000	349	165	514	51
Sm. ny.	600	206	172	378	63
Total	1,600	555	337	892	56
		w.t.-R			
Ad. & md. ny.	1,000	123	309	432	43
Sm. ny.	600	183	336	519	86
Total	1,600	306	645	951	59

[a]Based on assumption that adults in final collections (Table 6) include adults and medium-sized nymphs (md. ny.) of the original population and that medium-large nymphs are survivors of the small nymphs of the original population.

DATA FROM EXPERIMENT 3 (Aug.-Sept. 1983)

Location different from that of the other experiments

Table 8. Comparison of kill of a susceptible (orange-body) strain to that of a baygon-resistant (wild-type) strain of B. germanica following an initial treatment with 1% baygon in oil.

Strain	No. killed				
	Ad. ♀	Ad. ♂	Md. ny.	Sm. ny	Total
or-S	62	75	122	155	414
w.t.-R	25	58	78	101	262

Table 9. Collections at 2 weeks after initial treatment.

Strain	Collection	Ad. ♀	Ad. ♂	md-lg. ny.[a]	Sm. ny[b]
or-S	Carton	0	0	0	0
	Cleanout	68	72	70	50
	Trap[c]	5	2	0	0
w.t.-R	Carton	0	0	1	5
	Cleanout	99	58	183	291
	Trap[c]	4	2	2	21

[a]Small nymphs of original population an possibly some medium nymphs that had not matured.

[b]New hatch (1st instar). Additions to the population from hatch of egg cases carried by females of the original population.

[c]Trap bagged and counted in the laboratory.

Table 10. Comparisons of the total of all collections to those of the original population.

Age class	No. rel.	Initial kill	Survivors[a]	Cockroaches accounted for: No.	%
Ad. & Md. ny.	750	259	148	407	54
Sm. ny.	450	155	70[b]	225	50
Total	1,200	414	218	632	53
		w.t.-R			
Ad. & Md. ny.	750	161	163	324	43
Sm. ny.	450	101	186[b]	287	64
Total	1,200	262	349	611	51

[a]Based on an assumption that adults in final collections (Table 9) include adults and medium-sized nymphs (Md. ny.) of the original population and that medium and large nymphs are survivors of the small nymphs of the original population.

[b]Data not yet separated to show numbers of last instar nymphs that should be grouped with surviving "Ad. & Md. ny", i.e., that are most likely to be medium-sized nymphs of the original population that were about to mature.

Table 11. Response of adult males to filter papers with prior exposure to 100 gravid and 100 non-gravid females.

Time (hrs.)	Replicate[a]																			
	#1				#2				#3				#4				#5			
	Ct.	j.b.	Gv	non-gv	Ct.	j.b.	Gv.	non-gv	Ct.	j.b.	gv	non-gv	Ct.	j.b.	gv	non-gv	Ct.	j.b.	gv	non-gv
0.5	3	9	0	0	1	10	1	0	1	10	1	0	0	9	1	2	2	10	0	0
1.0	4	5	4	3	4	1	6	1	4	1	6	1	10	0	0	2	5	2	3	2
1.5	8	2	1	1	5	0	6	1	5	0	6	1	9	1	0	2	7	0	4	1
2.0	11	1	0	0	9	0	3	0	9	0	3	0	10	1	0	1	9	0	3	0
2.5	11	0	0	1	9	1	2	0	9	1	2	0	10	0	0	2	9	1	2	0
3.0	12	0	0	0	9	0	3	0	10	0	2	0	10	0	0	2	10	0	2	0
3.5	12	0	0	0	9	0	2	1	9	0	3	0	9	1	0	2	10	0	2	0
4.0	11	1	0	0	9	1	0	2	9	0	2	1	9	1	0	2	10	0	2	0
4.5	12	0	0	0	9	1	0	2	9	1	0	2	10	0	0	2	11	0	1	0
5.0	12	0	0	0	8	0	2	2	9	1	0	2	10	0	0	2	11	0	1	0

[a]Data categorized as follow: Ct.-control paper; j.b.-jar bottom; Gv.-paper exposed to gravid females; Non-gv.-paper exposed to non-gravid females.

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